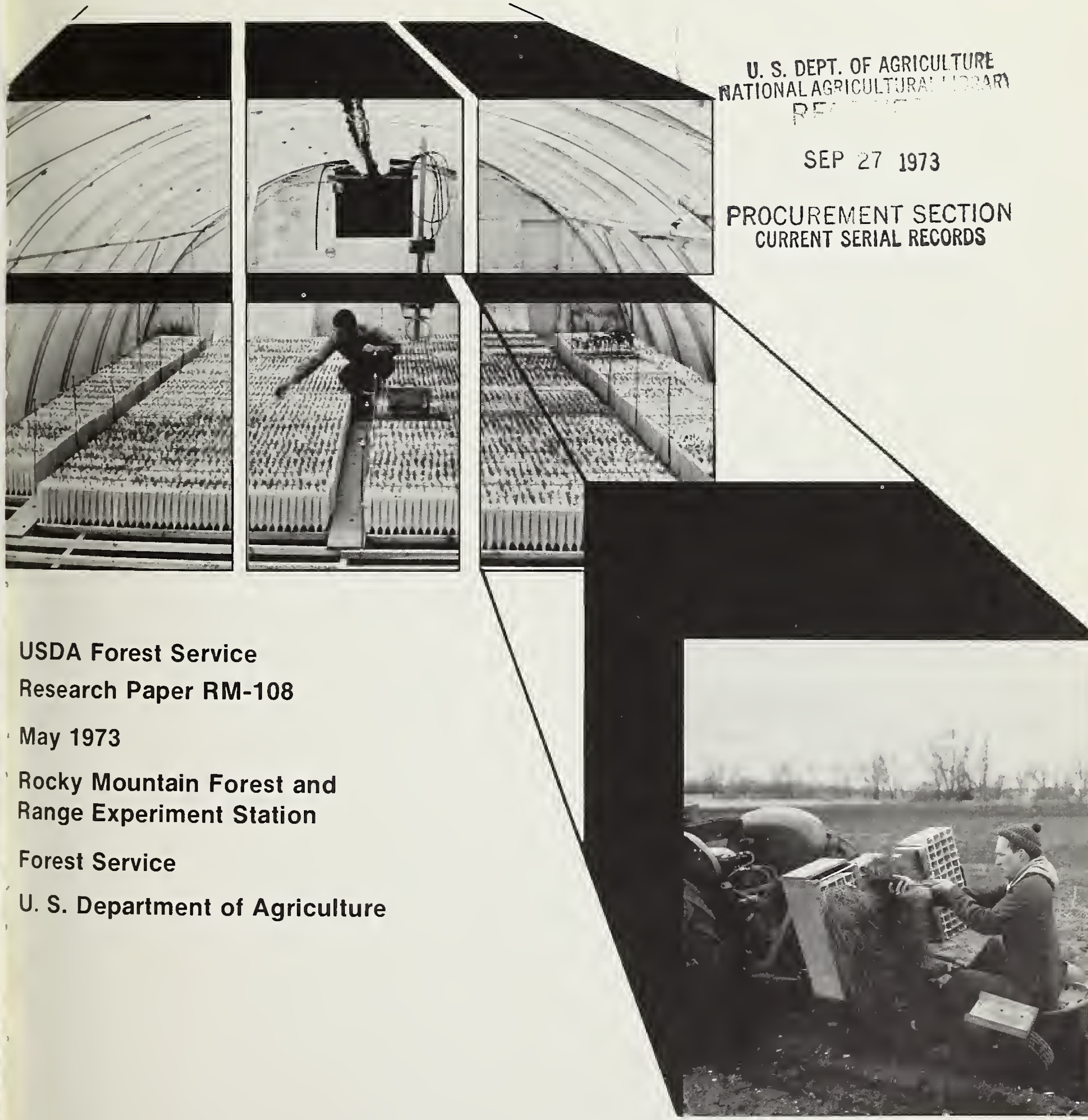
Economics of Containerized Conifer Seedlings

Marilyn K. Colby and Gordon D. Lewis



USDA Forest Service
Research Paper RM-108
May 1973
Rocky Mountain Forest and
Range Experiment Station
Forest Service
U. S. Department of Agriculture

Abstract

Containerized seedlings, grown in a newly developed, controlled environment greenhouse, can substantially reduce the time required to produce high quality seedlings, improve seedling survival rates in outplantings, and reduce net reforestation and afforestation costs. Plantable containerized stock can be produced in a greenhouse in 1 year as compared to 2 years for bare-root nursery stock and 3 years for potted seedlings. Moreover, the survival rate in outplantings for containerized seedlings is expected to be equal that for potted stock and almost twice that for bare-root stock. As a result, the costs per thousand surviving trees are estimated to be $460 for 2-0 bare-root stock, $441 for 2-1 potted stock, and $393 for containerized greenhouse seedlings. An equation is presented for determining the cost per thousand trees and for comparing between systems.

Oxford: 232.329.6:651.72. **Keywords:** Reforestation, planting (forest), nursery stock (forestry), regeneration (economic evaluation).

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Research Paper RM-108

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Contents

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Marilyn K. Colby and Gordon D. Lewis

Bare-root conifer seedlings grown in conventional forest tree nurseries are used in most reforestation efforts in the Rocky Mountain region. Bare-root stock is easy to handle and plant, and is relatively inexpensive to produce, but survival can be a problem in the varied climatic and topographic conditions found in the West.

The major problems relating to the production and use of nursery grown bare-root stock involve time and survival. Because it takes 2 to 3 years to grow nursery stock, the demand for seedlings must be predicted several years ahead. The long period in the nursery also exposes the seedlings to adverse weather, and disease and insect damage while in the seedbed, and lifting and storage must be coordinated with the length of the planting season, potential moisture, and site conditions.

Bare-root seedlings suffer root damage during lifting, and a drastic change in environment during lifting, packing, storage, transporting, and transplanting. These shocks adversely affect initial survival and growth rates after outplanting.

Potting procedures have been devised in an effort to improve survival under adverse soil and climate conditions on the planting site. Trees are lifted from the seedbeds or transplant beds as small bare-root seedlings, placed in tarpaper pots filled with soil or other suitable potting materials, and allowed to grow for an additional year or more. The potted seedlings are then outplanted, container and all.

The primary benefits of potting have been increased survival and growth rates of newly planted trees since the roots are not divested of soil. Potting seedlings is relatively expensive, however, and the other problems of growing nursery seedlings remain. In addition, transportation and planting costs may be significantly increased.

A process for growing containerized conifer seedlings in greenhouses is currently being explored to offset the disadvantages of nursery operations. The seeds are placed directly into a container with growing media, and germinated and grown under some form of enclosed environmental regulation. These environmental systems may range from simple regulation of heating and ventilation to careful control of heating and cooling, special lighting to prevent dormancy, a carbon dioxide enriched atmosphere, mycorrhizal inoculation, and automatic watering and fertilizing.[2]

The containerized greenhouse seedling system solves many of the traditional nursery problems. Trees are protected from weather, and the disease and insect problems normally encountered in the open atmosphere can be controlled. The greenhouse site may be selected with more regard for convenient location than for climate, topography, or soil. Size of area is not too important, since 1 acre can support 1 million trees or more. Estimated capacity of a greenhouse structure 120 by 34 feet is 110,000 seedlings in large (2- by 2- by 8-inch) containers. Since greenhouse operations can be highly mechanized, the importance of labor supply and labor costs are diminished.

Container systems are capable of producing trees quickly, and do not entail prediction of demand several years hence. Depending on the type of system, conifer seedlings grown in greenhouses may be ready for outplanting in less than one-third the time required for those grown in conventional nurseries. Survival and growth rates are usually improved over those for bare-root stock, especially on adverse sites for early- or late-season planting.

The principal drawback to the greenhouse system is that production costs are higher than those for bare-root stock. For a simple, open system the difference may be slight, but for the closed greenhouse system, production costs per thousand plantable trees may exceed those for bare-root stock by a factor of two or three. Transportation costs also increase, because the containers and growing media are shipped along with the trees. Planting costs may be greater, smaller, or remain the same, depending on methods and planting sites.

[2]*Much of the experimental work with the closed greenhouse system has been done by Richard W. Tinus, Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota.*

The problem, then, is to choose among systems for growing stock for outplanting. Bare-root nursery stock is cheaper to produce, but has several drawbacks. Potting improves survival and growth rates, but is more costly. Containerization eliminates most of the difficulties associated with nursery production, but is also more expensive.

This Paper will compare relative costs of the three methods in terms of planting conditions in the Rocky Mountains. Although it is not possible to quantify all the elements involved, many of the most important factors can be stated in terms of dollars. There will be four primary areas of consideration: the cost of producing seedlings, transportation costs, planting costs, and survival rates. All initial costs are based on 1,000 plantable trees.

Factors Considered

Costs of Production

The costs of seedling production can be divided into two major categories, direct and indirect. Direct costs for the bare-root nursery include seedbed preparation and seeding, weeding, fertilization, irrigation, lifting and packing, cold storage, and all other costs directly connected with tree production. For potted stock, the cost would also include labor for potting and potting materials. Direct costs of greenhouse production would include those for containers, growing media, fertilizer, water, electricity, gas, greenhouse maintenance, and labor associated with the setup and maintenance of the operation. The primary differences between the nursery and greenhouse systems are that (1) the nursery system is more labor intensive, with a large amount of the cost attributable to wages, and (2) in the greenhouse system, utilities which maintain the controlled environment account for most of the costs.

Indirect costs consist mainly of administration and depreciation of facilities. There is no reason to believe that administration will vary greatly among the systems. The capital investment for the greenhouse, associated structures, and equipment is high, and as a result, depreciation per thousand plantable trees is relatively high. In the West, however, containerized seedlings are held for a year or less, as opposed to 2 or 3 years for bare-root and potted trees. Accumulated depreciation attributed to nursery stock may therefore approach the amount ascribed to greenhouse seedlings.

Total production costs of containerized seedlings may vary from little more than bare-root stock up to three times as much.

Transportation Costs

Transportation costs of containerized stock increase with the size of container, because containers and growing media are transported along with the seedlings. For instance, a large tractor-trailer can carry 300,000 to 500,000 bare-root seedlings, but only between 17,000 and 20,000 large potted seedlings. Shipping costs per tree for large (2- by 2- by 8-inch) containerized or potted stock are estimated to run from $0.02 to $0.10 per tree ($20 to $100 per thousand). Shipping costs for bare-root stock are less than $0.005 per tree ($1 to $5 per thousand).[3] Although absolute transportation costs vary directly with distance from nursery to planting site, relative cost differences between types of stock should be similar regardless of hauling distance.

Where planting jobs are relatively small, transportation costs for bare-root stock may be relatively higher. For instance, at a spacing of 680 trees per acre, a truckload of 300,000 bare-root seedlings should be enough to plant 440 acres. Shipment of fewer trees in the same vehicle would increase transportation cost per thousand trees.

Planting Costs

Large variations in planting costs have been noted for both bare-root and containerized seedlings. Excluding site preparation, hand planting of bare-root seedlings has cost as little as $30 per thousand in Colorado, and more than $300 per thousand in Wyoming. Reported costs of hand planting containers run from $15 per thousand to $100 per thousand seedlings, with the higher cost attributable to the larger containers.

Costs on National Forest sites, which may be expected to run somewhat higher, have been about the same for hand planting both bare-root stock and containers under similar conditions.

Costs for machine planting the two types of seedlings are very similar. A tree planter is easily adapted to containerized stock, especially where the seedlings are removed from the containers as they are planted ("plug"-type seedlings).

[3] *Transportation cost estimates were determined from information furnished by Marvin D. Strachan, Colorado State Forest Service, Fort Collins, Colorado; Richard W. Tinus, Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota; John A. Adams, U.S. Forest Service, R-8, Atlanta, Georgia; and C.D. McAninch, U.S. Forest Service R-2, Denver, Colorado.*

Survival Rates

Survival rates probably give the most valuable comparison between the various types of seedling production. High initial survival rates will result in a well-stocked stand sooner, and will reduce or eliminate replanting costs.

In most cases, greenhouse seedlings survive better than bare-root seedlings, particularly on adverse sites and under difficult planting conditions. For instance, in Montana, August plantings of bare-root ponderosa pine are usually total failures, while first-year survival of containerized stock may be almost 90 percent.[4] Poor survival of bare-root seedlings would require replanting to achieve the minimum acceptable survival rate.

Some increased growth is also realized the first year or two with container stock, but there is little advantage after the trees are reasonably well established.

A Comparative Example

To evaluate the cost relationships, a comparison was drawn for ponderosa pine raised under three different systems. The three types of stock are 2-0 bare-root stock, grown at the USDA Forest Service's Mount Sopris Nursery at Carbondale, Colorado; 2-1 potted stock of the type produced by the Colorado State Forest Service Nursery at Fort Collins, Colorado; and containerized seedlings of the type to be produced in a greenhouse planned for the Mount Sopris Nursery.

A 2-0 bare-root seedling was defined as one which has spent 2 years in the seedbed, and has had the soil removed from the roots at the time of lifting for outplanting. A 2-1 potted seedling has been grown in the seedbed for 2 years, then lifted and placed in a pot, where it has remained 1 year. A 1-0 greenhouse containerized seedling has been seeded directly into its container and grown under controlled conditions for 1 year. A plug-type containerized seedling is removed, with root ball intact, from the container immediately before planting.

A 3-0 bare-root seedling is approximately the same size as 2-1 potted stock and 1-0 greenhouse stock. However, no 3-0 ponderosa pine is used in the Rocky Mountain Region (Region 2, USDA Forest Service), as 2-0 bare-root stock appears to have better survival and a better top/root ratio.

[4]*Correspondence with Wayne Hite, Anaconda Forest Products, Bonner, Montana.*

Production Costs

Costs of producing 2-0 bare-root stock were based on cost determinations for Mount Sopris Nursery for fiscal years 1971 and 1972. Costs were broken down on a year-by-year basis and compounded at 5 percent annually to incorporate the length of growing period. No allowance was made for inflation.

Costs of producing 2-1 potted stock were based on information obtained from Marvin Strachan, Colorado State Forest Service Nursery. Costs were compounded at 5 percent annually to incorporate the length of growing period. No allowance was made for inflation.

Greenhouse production costs were based on a 1-year cycle in the proposed structure for the Mount Sopris Nursery. Setup and operating costs for the cycle were derived from records for a smaller experimental greenhouse operated during 1971-72 by the Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota. Costs are detailed in tables 1 and 2.

Transportation Costs

Transportation costs for bare-root seedlings were approximated from Mount Sopris costs for fiscal year 1972. For potted seedlings, the transportation costs were an average of estimates from various sources. They indicate that the cost is 5 to 25 times higher for potted seedlings than for bare-root stock.

Transportation costs of containerized seedlings were assumed to be basically the same as for potted seedlings, as the containers are about the same size. Because the plug-type seedlings are moved in blocks of containers, however, and up to 20 percent of the containers may not contain a plantable seedling, transportation costs per plantable seedling were somewhat higher than for the potted stock.

Planting Costs

Planting costs for bare-root stock were based on average contract costs for Region 2, USDA Forest Service. Because no data were available for container planting in the Region, planting costs were assumed to be slightly higher for container and potted stock due to bulk and weight.

Survival Rates

Survival rates were based on unpublished information on file in Timber Management

Table 1.--Projected capital cost and depreciation for proposed greenhouse at USDA Forest Service Mount Sopris Nursery, Carbondale, Colorado[1]

Item	Total cost	Depreciation per--	
		Year[2]	1,000 plantable trees[3]
Mechanical-electrical systems:			
Pad cooling system	$ 2,800	$ 80.00	$ 0.91
Exhaust fan system	1,050	30.00	.34
Heating system	3,800	108.57	1.23
Watering system	1,500	42.86	.49
Lighting system	2,600	74.29	.84
CO_2 generator system	150	4.29	.05
Controls and wiring	4,000	114.29	1.30
Total	15,900	454.30	5.16
Greenhouse	18,000	514.29	5.84
Utilities	1,500	42.86	.49
Buildings[4]	--	220.00	2.50
Total	$35,400	$1,231.45	$13.99

[1]Proposal is a modification of a greenhouse project designed for the State of Kansas by Region 2, USDA Forest Service.

[2]Depreciation for fiberglass greenhouse structure and associated equipment was calculated by straight-line method over a 35-year life.

[3]Estimated greenhouse capacity is 110,000 trees, 80 percent of which are plantable at end of cycle.

[4]Existing buildings will perform functions of headhouse; depreciation for buildings was determined by Region 2, USDA Forest Service.

Research, Rocky Mountain Forest and Range Experiment Station, Fort Collins, Colorado, and Anaconda Forest Products, Bonner, Montana. The survival rate for bare-root stock in the Rocky Mountain region is most likely to fall somewhere between 25 and 50 percent, perhaps somewhat higher on the better sites. In general, it appears that large greenhouse seedlings and potted stock both survive better than bare-root seedlings, especially under adverse conditions.

Cost of Surviving Trees

In this example, the cost of producing 2-0 bare-root stock was $52.18 per thousand (table 3); that of producing 2-1 potted stock was much higher at $197.12 per thousand; and the cost of greenhouse seedlings was intermediate at $145.81 per thousand. These were costs per thousand plantable trees, and included an allowance for losses in the nursery or greenhouse.

Transportation charges were much higher for potted and containerized seedlings, due to the transportation of bulky pots and soil (table 3). This difference would become more pronounced the farther the hauling distance, and would be one argument for locating a greenhouse in an area reasonably close to prospective planting sites. This choice is not always possible when bare-root stock is considered.

The third major category in table 3 is site preparation and planting. Region 2, USDA Forest Service, estimates average contract costs for this operation to be $0.12 per seedling, with

Table 2.--Projected cost of tree production for proposed greenhouse at Mount Sopris Nursery, Carbondale, Colorado[1] (labor was estimated at $3 per hour for all activities)

Item	Costs per-- 1-year cycle	Costs per-- 1,000 plantable trees[2]
Setup:		
Containers[3]	$ 3,300	$ 37.50
Container assembly	935	10.62
Peat and perlite	240	2.73
Fertilizer	515	5.85
Replace fiberglass	375	4.26
Fill, seed, transfer	1,325	15.06
Total	6,690	76.02
Operation:		
Electricity	1,800	20.45
Fuel	1,200	13.64
Repairs	1,500	17.05
Routine care	360	4.09
Emergency care	50	.57
Total	4,910	55.80
Total direct cost	11,600	131.82
Depreciation[4]	1,231	13.99
Total cost	$12,831	$145.81

[1]Estimated from figures furnished by Richard W. Tinus, Shelterbelt Laboratory, Rocky Mountain Forest and Range Experiment Station, Bottineau, North Dakota, for a pilot model greenhouse, and from specifications for the Kansas project.

[2]88,000 trees (80 percent of capacity) assumed plantable.

[3]The containers considered here are serviceable for only one cycle; cost would decrease if reusable containers are employed.

[4]See table 1.

an additional cost of $30 per thousand seedlings for contracting and supervision. This results in a total cost of $150.00 per 1,000 seedlings for site preparation and hand planting for bare-root stock. No estimates were available for planting costs of containerized stock in Region 2. However, the Colorado State Forest Service estimates that, because potted and containerized stock is bulkier and heavier to handle, planting costs should be about $20.00 per 1,000 seedlings more than those for bare-root stock. Site preparation costs are the same for both types of planting stock.

Total cost per thousand trees planted was determined by adding production cost, transportation cost, and planting cost (table 3). For bare-root stock, the figure was $207.18; for potted stock, $397.12; and for greenhouse seedlings, $353.31.

The comparative benefits of the three methods were measured as survival rates. By dividing the appropriate survival figure into cost per thousand planted trees, cost per thousand surviving trees was determined. On the basis of table 3, the greenhouse seedling had the lowest cost per surviving thousand trees, $392.57. Potted seedlings were more expensive at $441.24 per thousand, and bare-root stock had the highest price at $460.40 per thousand.

Table 3.--Relative costs for establishing ponderosa pine 2-0 bare-root, 2-1 potted, and 1-0 greenhouse stock

Type of cost	Cost or rate per thousand plantable trees[1]		
	2-0 Bare-root	2-1 Potted	1-0 Greenhouse
Production costs:[2]			
1st (seed) year	$ 20.15	$ 30.87	$145.81
2nd year	13.35	26.25	--
3rd (potting) year	--	100.00	--
Lift (sort) year	18.68	40.00	--
Total	52.18	197.12	145.81
Transportation costs	5.00	30.00	37.50
Site preparation and planting costs	150.00	170.00	170.00
Total cost of trees planted	207.18	397.12	353.31
Survival rate	45 percent	90 percent	90 percent
Cost per thousand surviving trees	$460.40	$441.24	$392.57

[1]All costs incurred during the growing season are prorated to plantable trees. Sources of data are discussed in text.
[2]For comparison, all production costs were compounded at 5 percent per year to year of planting.

A Comparative Equation

The same general procedure used to construct table 3 can be applied to any specific instance where greenhouse production is considered in competition with nursery stock. If all four items (cost of production, transportation cost, planting cost, and survival rate) are known or can be approximated, the best system can be determined by a simple formula:

$$X_1 = \frac{Pr_1 + T_1 + P_1}{S_1} \gtreqless \frac{Pr_2 + T_2 + P_2}{S_2} = X_2 \qquad [1]$$

where

X = Total cost per thousand surviving trees.
Pr = Production cost per thousand plantable seedlings, including depreciation and overhead. To account for length of holding period, compound annual costs incurred prior to the planting year at an appropriate interest rate.
T = Transportation cost per thousand plantable seedlings from production site to planting site.
P = Site preparation and planting cost per thousand trees.
S = Survival rate of trees planted, preferably at the time trees are considered established.
1 = Data for the greenhouse system.
2 = Data for any alternative system.

If X_1 is less than X_2, the greenhouse system is less expensive.

Using the figures for bare-root and greenhouse stock in table 3, the analysis would be:

$$X_1 = \frac{\$145.81 + 37.50 + 170.00}{0.90}$$

$$\gtreqless \frac{52.18 + 5.00 + 150.00}{0.45} = X_2$$

$$X_1 = 392.57 < 460.40 = X_2$$

A change in any of the four major factors will affect the relationship between the methods. Suppose that for a particular project all costs are the same as those in table 3, except that planting costs of potted and greenhouse stock are estimated at $200 per thousand, and because the site is more favorable, the survival rate is estimated to be 65 percent for bare-root stock and 95 percent for potted and greenhouse stock. Under these conditions, potted stock would be the most expensive at $449.60 per thousand, greenhouse seedlings would be cheaper at $403.48 per thousand, but bare-root stock would be the least costly at $318.74 per thousand.

The magnitude of the difference between two systems is important. Where the difference is small, a minute change in any one factor could reverse the result, and nonmonetary considerations would influence the decision. On the other hand, if the difference was large, conditions would have to be altered greatly to change the cost/benefit outcome.

If any one of the factors is unknown, a break-even value can be determined. Given the following costs per thousand surviving seedlings:

	Greenhouse	Bare-root
Production	$150	$50
Transportation	50	5
Planting	100	75

what survival rate would be required to economically justify the use of greenhouse seedlings? If survival of bare-root seedlings is expected to be 40 percent, the procedure would be as follows, using greenhouse survival (Z) as the unknown:

$$\frac{150 + 50 + 100}{Z} \leq \frac{50 + 5 + 75}{0.4}$$

$$\frac{300}{Z} \leq 325$$

$$Z \geq 0.923 \text{ or } 92.3 \text{ percent}$$

Survival of greenhouse seedlings then, would have to be quite high to compensate for their greater cost of production, transportation, and planting.

Replanting must be considered where a minimum acceptable standard exists, such as in shelterbelts, where 80 percent is desirable. On many forest lands, 50 percent or less would be considered adequate, depending on spacing in the plantation. If a minimum acceptable rate of survival is 50 percent of the original planting density, then, for the situation represented in table 3, the bare-root stock would have to be replanted once. The other two types would not have to be replanted. **Cost per surviving tree** would not change for bare-root stock, but replanting would reduce the amount of land which could be planted each season, and **cost per acre** would increase each time the site was replanted.

Conclusions

The higher initial costs associated with the greenhouse system can be offset by better survival. From an economic standpoint this is especially important where adverse sites must be regenerated quickly. This factor can be partially taken into account by penalizing the slower growing nursery stock through the use of a higher interest rate in compounding costs to the planting year. Additional benefits such as quality control through the use of genetically improved seed and the capacity for sounder planning and a more flexible operation may be obtained, but little specific information is presently available.

Nursery costs are rising, largely because nurseries are labor-intensive operations, and labor costs are increasing. This trend will have less effect on the greenhouse system, since it is more capital-intensive and requires little labor.

Similarly, container systems do not require the same quality in land that nursery systems do, nor do they require the quantities of land needed for nursery operation. Where land values are high and/or rising, the greenhouse system could represent considerable cost saving.

Because the techniques are new, the cost of greenhouse container seedlings should decrease with technological improvements, more mechanization, and a better internal survival rate. On the other hand, nursery procedures have been pretty well standardized, and improvement cannot be expected at the same rate as in greenhouse nurseries.

Another factor that can decrease the cost of greenhouse seedlings is a scale economy effect due to better utilization of auxiliary buildings and management. This effect would be valid up to about 500,000 seedlings for the greenhouse system presented in tables 1 and 2.

Because planting costs are high, more needs to be known about the differences between planting containerized seedlings and other stock, and how these differences influence costs.

In summary, the production of containerized greenhouse seedlings appears to be favorable in the light of current trends. Much remains to be learned, however, about the economics and physical capabilities of various types of greenhouses, and the economic/biological trade-offs related to various levels of environmental control.

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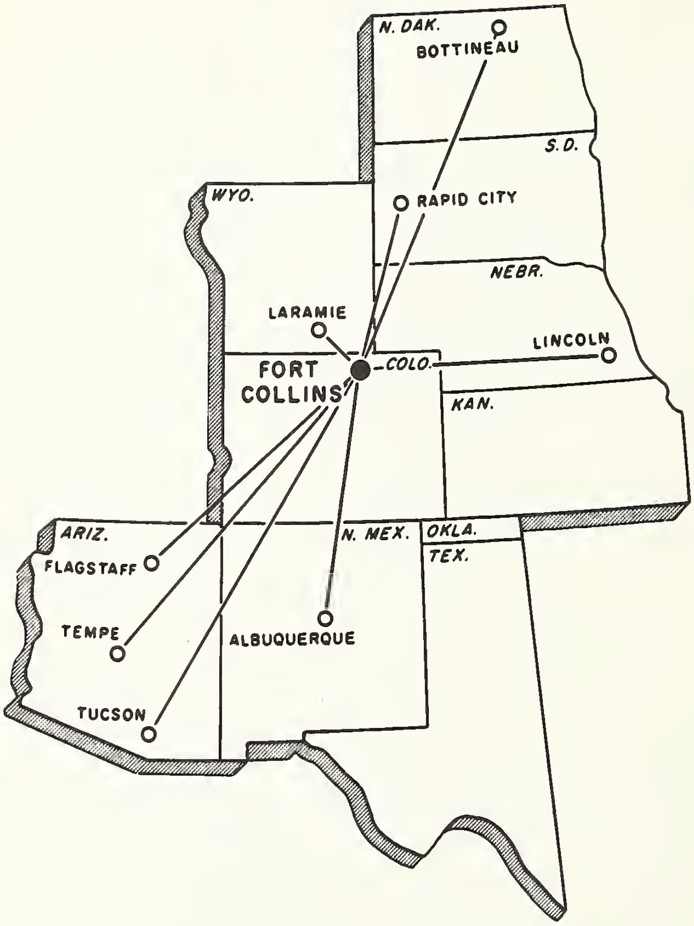
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